Coating Fabrication Issues

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Presented to:
Office of Pipeline Safety Workshop on
Advanced Coatings R&D for Pipelines and Related Facilities
June 9-10, 2005
National Institute of Standards and Technology
Gaithersburg, MD USA

Pipeline Coatings

The role of external pipeline coatings is to complement cathodic protection systems in protecting pipelines from corrosion and subsequent failure

Demands

- Improved pipeline integrity
- Improved coating performance.
  - increased reliability
  - less risk of failures
  - longer expected lifetime
  - less maintenance
- Improved quality
- Increased capabilities
  - higher pipeline operating temperatures
  - low temperature construction in arctic regions
- Environmental concerns
- Improved life cycle economics
  - material costs
  - construction & operating costs

Strategy for Achieving Pipeline Integrity

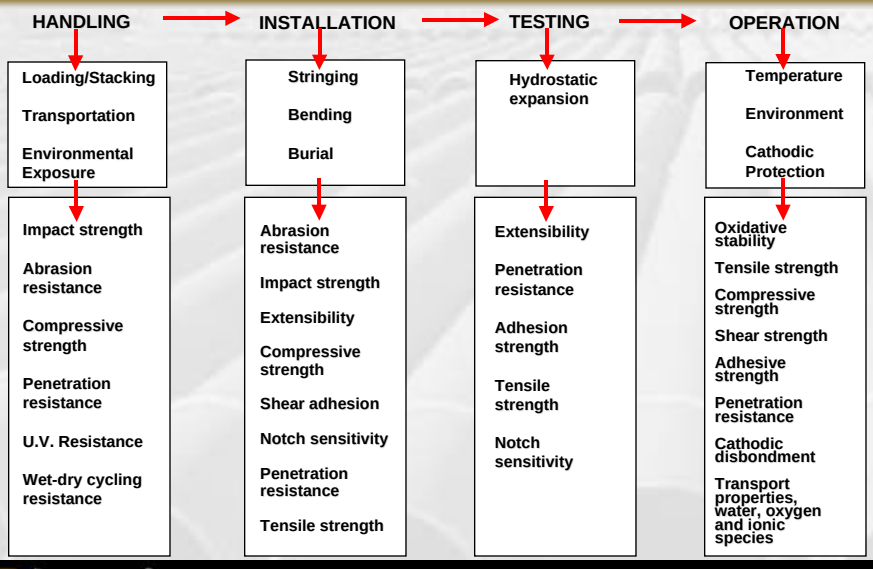
- Develop understanding of coating performance requirements
- Design and select coatings properly
- Ensure meaningful specifications are written
- Apply coating under optimum process with adequate quality control
- Carry out construction according to plan
- Operate system within specification
- Periodic monitoring and feedback on performance
- Research & Development of new technologies

Requirements

CSA Z662:

- 9.2.7.1 properties: coating shall
- a) electrically isolate the external surface of the piping from the environment;
- b) have sufficient adhesion to effectively resist underfilm migration of moisture;
- c) be sufficiently ductile to resist cracking;
- d) have sufficient strength and adhesion - to resist damage due to soil stress and normal handling (including bending, concrete coating application, river/swamp weight installation, and anode bracelet installation, where applicable);
- e) be compatible with cathodic protection;
- f) resist degradation of the coating properties throughout - conditions and temperatures encountered during storage, shipping, construction, and operation;
- g) where plant-applied and applicable to the coating system to be used, be in accordance with CSA standard Z245.20 or Z245.21

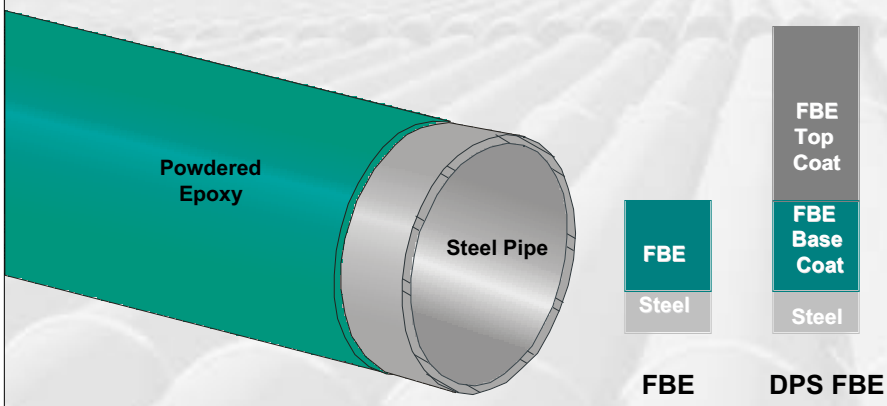
Matching Coating Properties to Integrity Issues



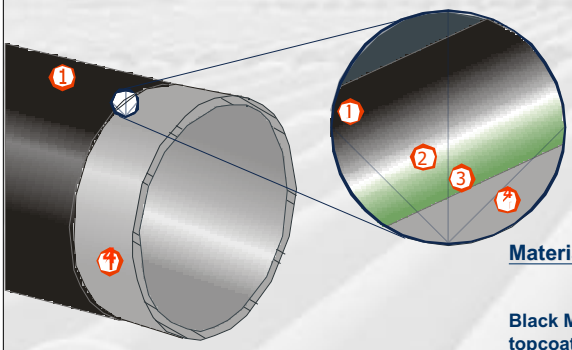
Plant Coating Technologies

- Powder Applied Coatings
  - FBE
    - Single layer: corrosion and specialty
    - Multi-layer: abrasion, anti-slip, protective topcoat
  - HPCC
    - Multi-component: FBE, adhesive, PE or PP topcoat
- Extrusion Applied Coatings
  - 2 layer PE/PP
    - Mastic adhesive, butyl, hot melt
  - 3 layer PE/PP
    - FBE, adhesive, PE or PP topcoat
- Liquid Applied Coatings
  - Polyurethane, epoxy, coal tar enamel, asphalt enamel

Fusion Bonded Epoxy



HPCC



1. Black MPDE Topcoat
2. FBE/Adhesive Interlayer
3. FBE Primer
4. Steel Pipe

Material	Standard Thickness
Black MPDE topcoat	500 micron (20 mils)
FBE/Adhesive Interlayer	125 microns (5 mils)
FBE	125 microns (5 mils)
TOTAL	750 microns (30 mils)

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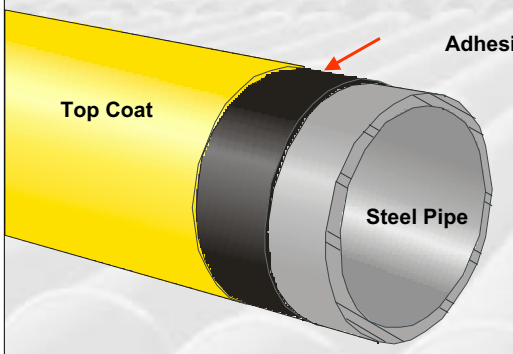
2 Layer PE/PP



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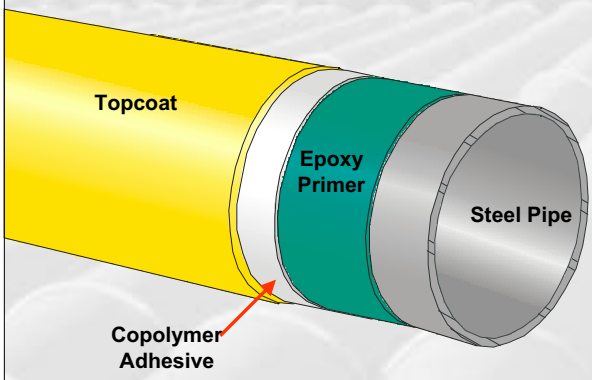
3 Layer PE/PP



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Field Coating Technologies

- Powder Applied Coatings
  - FBE
    - Single layer
    - Multi-layer
  - Multi-component
    - FBE, adhesive, PE or PP topcoat
- Liquid Applied Coatings
  - Polyurethane, epoxy
- Heat Shrink Sleeves
  - Crosslinked PE/PP with/out liquid epoxy
- Others
  - Tapes, sleeves, etc.

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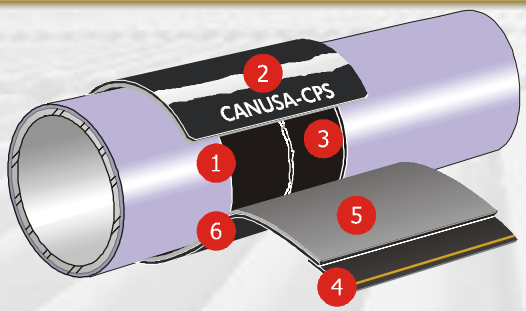
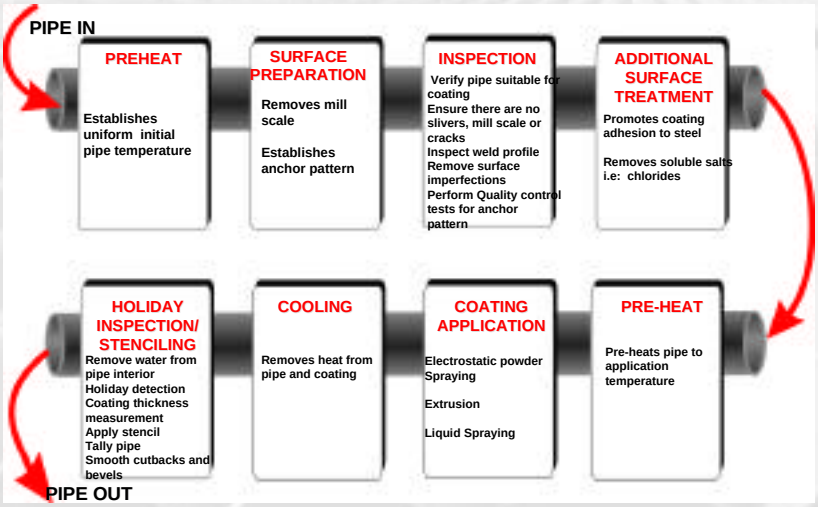
Heat Shrink Sleeve

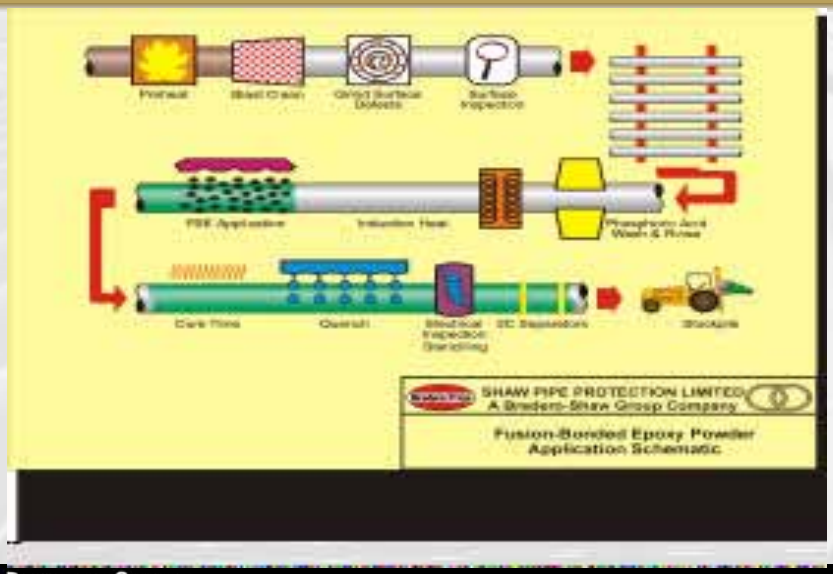


1. Adhesive Directly To Line Coating
2. CrossLinked Backing
3. Force Cured Epoxy System
4. Pre-attached Closure System
5. "Open" Adhesive Technology
6. Epoxy On Steel Only

Typical Process



FBE Coating Process



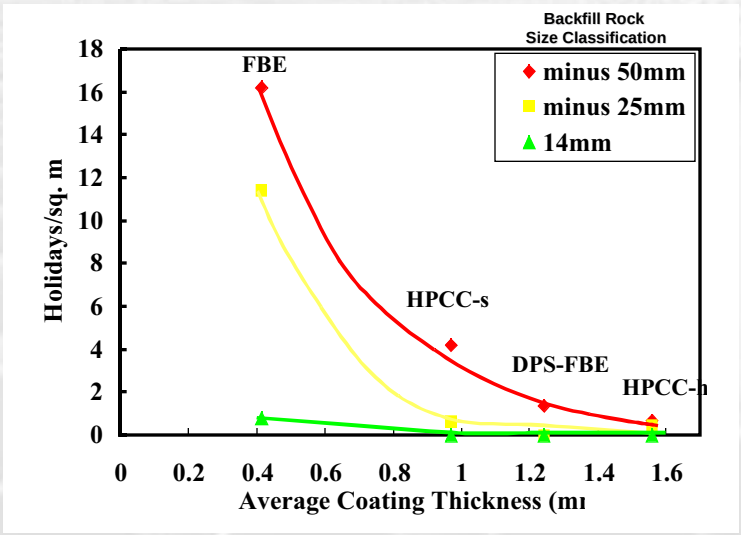
Design & Selection

Need better understanding of performance requirements to quantify and select

Many studies on various properties, for example:

- **Impact**
- **Shear adhesion**
- **Thermal aging**
- **UV degradation**
- **Cathodic disbondment**
- **Cathodic protection**

Indentation Resistance



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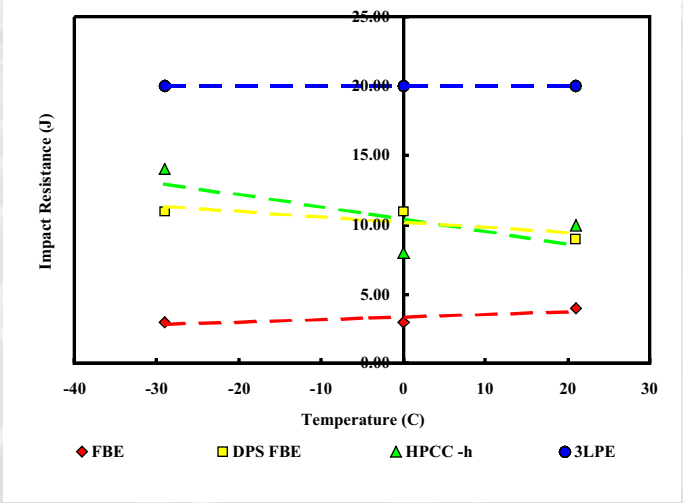
Impact



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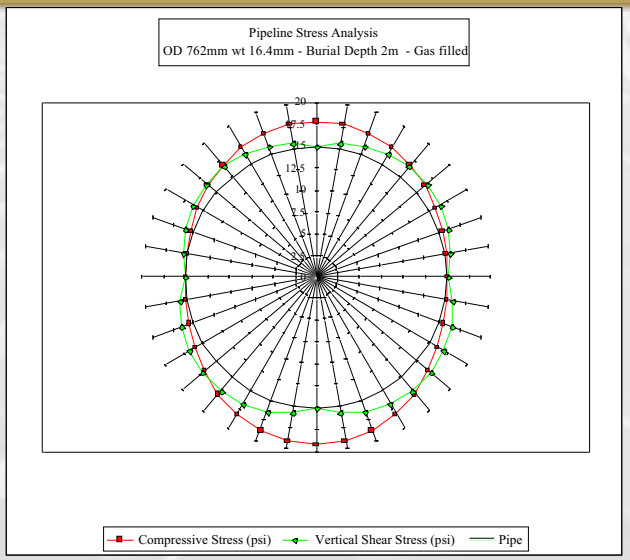
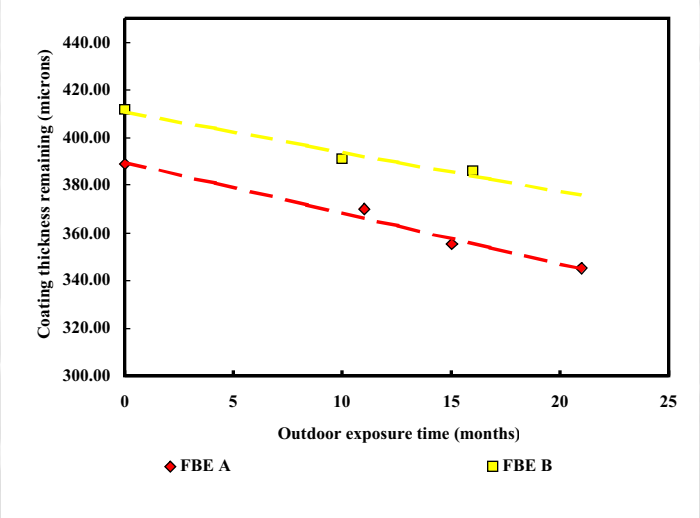
Buried Pipeline Stress Analysis



FBE thickness vs Stockpile time



Specifications

- Need for standardization
  - Proliferation of company exclusive specifications
  - Many differences, some good, some bad
  - ISO standards being developed
- Need for performance based specifications
  - Define performance requirements not manufacturing process
  - End result can be to stifle innovation, build in mediocrity with poor specifications
- Need for meaningful specification
  - More requirements, tighter criteria not often better
  - Focus on important properties and limits
  - Can deteriorate into testing project

Manufacturing Issues

- Complex application process
  - Many diverse processes to apply coatings: from heating, surface preparation, materials application
- Little consensus on best process/parameters
  - Some research on various parameters such as profile, contamination, surface treatments
  - Studies often not very conclusive
- Realistic expectations
  - Large heavy part/surface area to be coated
  - Process time limitations (delivery schedules)
  - Cost limitations as % of steel cost
  - Cannot treat in same manner as small components

Surface Preparation

- Most important process in determining coating quality
- Need to determine optimum parameters and how to measure during process
- Many companies do not understand importance
- Some coatings are more sensitive to level of preparation

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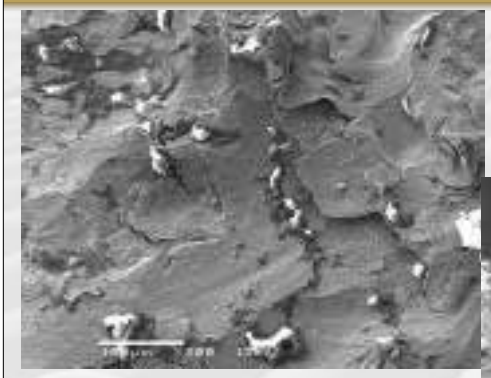
Optimum Blast Profile?



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Cross-head/side extrusion?

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Manufacturing Issues

- Not ideal manufacturing process
  - Cannot schedule, inventory management, etc)
- More similar to project driven business
  - Customer supplied pipe
  - Wait for pipe to be delivered and then coat
- Problems inherent to project driven industries
  - Inefficient if work is not steady
  - Issues on maintenance of skilled labour

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Incoming Pipe Quality

- May not be critical for pipeline itself but important for processing and coating application
- Condition of pipe on delivery
  - Wall thickness
  - Roundness
  - Camber
  - Weld profile
  - Steel cleanliness
  - Contamination
  - Joint length
- Steel pipe specification
  - Need to address not only pipeline design issues but also subsequent ability to process for coating

Quality Assurance

- Should be internally driven by coating applicator
  - customer should expect a high level QA program
- Quality improvement programs
  - awareness
  - preventative
  - inspection and audit
- Use of ISO 9001
  - Program regularly audited by third party

Industry Feedback is Important

- Assessment of coating performance in independent digs
- Confirmation of predictive analysis on long term coating properties
  - Adhesion
  - Permeability
  - Material properties
- Joint development of corrective strategies
- Operators, contractors, coaters, regulators, and engineering companies need to work as a team

Failure Modes

- Damaged Coating
  - Impact damage
  - Cracking
  - Deterioration
- Shielding Disbondment
  - Over the ditch tapes
- Permeable Coating
  - Asphalts and to some extent FBE
- Blistered Coating
  - Has been observed with FBE
- Disbondment
  - Has been observed with 3 layer PE and PP coatings

Blistered FBE

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3LPE Disbondment

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2LPE Cracking

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Tape Disbondment & Wrinkling

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Research

- Predictive studies
  - Predictive analysis of properties (long term)
  - Relation of lab measured properties to field performance
  - Development of models to use in design & selection of coatings
- Product/process development
  - New products to reduce failures, increase performance, increase reliability, lower cost
  - Standards need to be flexible to allow new developments
- Failure Analysis
  - Understanding coating failures
    - Blistering
    - Disbondment
    - Cracking

Competitive Issues

- Protection of innovative technologies
  - Patents, secrecy agreements
- Limits to access
  - Conflicts with end users specifying full access
- Intentional and accidental sharing of technologies
- Protection of R&D investment

Summary

- Design & selection of coatings
- Specification changes
  - ensure steel pipe is compatible to coating process
  - performance based
- Research
  - Develop design & predictive methodologies
  - Feedback of actual coating performance in service
  - New materials and processes to increase performance, reliability and reduce life cycle cost
- Competitive industry
  - Protection of innovative technologies
  - Payback of R&D investment